THE ORIGIN OF VEINLETS IN THE SILURIAN AND DEVONIAN STRATA OF CENTRAL NEW YORK[1]

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INTRODUCTION

Although the origin of metalliferous veins has long been of interest to the geologist and mining engineer, very few facts have been definitely established concerning the mechanics of vein formation. Direct investigation of the subject is difficult because of the complexity of the processes involved and because only the final results are available for examination. The evidence that may have existed during the early stages of vein growth has commonly been obliterated by alterations due to vein-forming solutions or to secondary changes. Most metalliferous veins are found in regions of dynamic metamorphism and where igneous processes have been active. Consequently these veins, as a rule, furnish little or no evidence relative to the mechanics of their origin. The study of small barren veins in regions of unaltered sedimentary rocks has been largely neglected because they are of no commercial importance, and yet such veins often furnish more positive evidence con-

[1] Presented in abstract at the Albany meeting of the Geological Society of America, December, 1916.

cerning the mechanics of vein formation than is to be found in the larger and more complex ones. It was for this reason that the present investigation was undertaken.

Many small veins are present in the Silurian and Devonian formations of central New York. These rocks are well exposed in the numerous limestone and gypsum quarries of Cayuga and Onondaga counties. In the summer of 1916 the writer visited all of the quarries now being worked in these counties and nearly all of those that are idle, but most of the data used in this paper were obtained in the extensive quarries found in the vicinity of Union Springs.

STRATIGRAPHIC FEATURES

The rock formations outcropping in the region studied are listed below:

Devonian
    Skaneateles shale
    Cardiff shale
    Marcellus shale
    Onondaga limestone
    Oriskany sandstone and conglomerate

Silurian
    Manlius limestone
    Roundout limestone
    Cobleskill limestone
    Bertie waterlime ⎫
    Camillus shale   ⎬ Salina formation
    (Syracuse salt) ⎪
    Vernon shale   ⎭

Rock salt in the form of lens-shaped beds is present at many places immediately below the Camillus shale, but it has been removed in solution wherever the covering is less than about 1,000 feet thick, and therefore is never found near the outcrops of the strata.[1]

The Camillus shale contains intercalated beds of impure magnesian limestone and of gypsum. The limestone layers are more abundant in the upper part of the shale and probably represent

[1] D. H. Newland and Henry Leighton, "Gypsum Deposits of New York," *N.Y. State Museum Bull. 143*, 1910, p. 21.

transitional stages toward the Bertie waterlime. The gypsum is highly argillaceous and in places grades into gypsiferous shales. Partings of shale, ranging in thickness from a fraction of a centimeter up to several meters, are usually present, dividing the gypsum into several beds. These beds thin out and disappear, so that their number and thickness vary greatly in different districts. In many sections they are entirely absent. Gypsum may be found in small quantities all the way from the bottom to the top of the Camillus shale, but usually most of it is near the top.

The Onondaga limestone is commercially the most important of the limestone beds, and therefore there are many quarries located all along its outcrop; but the Cobleskill and Manlius limestones are also being quarried at several places. The lower layers of the Onondaga limestone, locally known as "gray limestone," have a well-developed crystalline texture similar to that of marble. The limestone forming the upper portion is bluish gray in color, dense, fine-grained, and contains numerous nodular concretions of chert or hornstone. Microscopic examination shows that the "blue limestone" consists essentially of irregular grains of calcite and small crystals of pyrite, while rhombic crystals of calcite may occasionally be distinguished.

The chert varies in color from light bluish gray to almost black, and on freshly fractured surfaces is often difficult to distinguish by color or texture from the inclosing limestone (see Fig. 6). It is irregularly distributed, occurring often in small isolated nodules, though more commonly the nodules are arranged in well-defined rows or layers, and in places these layers of disconnected nodules pass by gradation into more or less continuous and uniform layers or bedded veins, which may be 3 cm. or more in width and extend for distances of many meters. The chert masses have evidently been formed through replacement of the limestone, for some of them contain fossils in which the details of structure are perfectly preserved. On weathered surfaces the chert, because of greater resistance, stands out in sharp relief. Microscopically the chert is cryptocrystalline, and the boundary between limestone and chert is not sharply defined. In passing from limestone to chert there is a gradual though rapid decrease in calcite with a correspond-

ing increase in silica, but all of the chert examined contains numerous inclusions of calcite in the form of rhombohedral crystals (0.05 mm. and less in diameter), somewhat larger than the similar rhombs in the limestone.

<div align="center">STRUCTURAL FEATURES</div>

The rock strata have been disturbed only slightly since their emergence from the sea. In general, the dip is toward the south at an average inclination of 7 to 10 m. per kilometer, but in a few places, because of gentle folding, there is locally considerable variation from this average.

Jointing is well developed throughout the area, and is probably due chiefly to the adjustment of strains resulting from folding and tilting. Appreciable openings are not found along these joints except near the surface, where, under favorable circumstances, they have been widened by the solvent action of descending surface water, and in such instances little or no deposition is to be observed on their walls. The fracturing of the rock strata seems to have resulted from compressive forces which would tend to prevent the formation of open fissures. The joints cut the veins of the region, and are therefore, in part at least, of later origin.

A thrust fault with displacement of a few centimeters is exposed in the Backus quarry, two miles north of Union Springs, and here the drag of the rock strata on both sides of the fault plane indicates that the displacement was accompanied by sufficient pressure to keep the fracture closed. A narrow vein of selenite follows this fault. Hopkins has described several thrust faults in the vicinity of Syracuse, the displacements ranging from a few centimeters to a little over a meter.[1]

Certain local disturbances of the rock strata, not noticeable in the overlying formations, may be observed in the Cobleskill limestone and the upper beds of the Salina. In places these strata have been pushed upward in such a way as to form low domelike elevations on which the joints sometimes have a radial arrangement. A group of six or more domes may be found a kilometer southeast

[1] T. C. Hopkins, "The Geology of the Syracuse Quadrangle," *N.Y. State Museum Bull. 171*, 1914, p. 29.

of Aurelius Station. They are strung out in a general north and south line near the bottom of a hill slope, and at the foot of the hill, close to the base of the domes, there are several large springs with deposits of calcareous tufa below them. A small quarry has been opened in one of the larger domes, which has a diameter of about 50 m. and height of 4 m.

Hartnagel[1] thinks that these domes are due to an increase in volume of the underlying beds, because of the formation of gypsum from anhydrite; but the present writer has found no evidence supporting this view. The shape of the domes, their location, and their general associations are such as to suggest that they have been formed in the same way as the salt and gypsum domes of Louisiana and elsewhere, which have been described and explained by Harris.[2] No open fissures, except where joints had been widened at the surface by weathering, and no veins were observed in any of the domes.

Open spaces of appreciable size are infrequent except in the upper beds of the Salina. The Bertie waterlime contains numerous small cavities attributed by Vanuxem to the solution of salt, since they sometimes exhibit the hopper-shaped outlines of halite crystals. The intercalated layers of magnesian limestone in the Camillus shale usually show the same porous structure and hopper-shaped casts. These cavities are frequently lined with a calcareous deposit. Small cavities, caused by the partial solution of fossils, are occasionally found in some of the limestones, and these openings are often lined with calcite, chalcedony, or crystals of quartz.

Open fissures of mechanical origin were found in only one locality, in Camillus shale exposed by a cut on the Lehigh Valley Railroad about 100 miles west of Cayuga Junction. The cracks are 1 cm. or more in width, and are partly filled with a calcareous deposit having the appearance of finely banded travertine or onyx marble, the layers of which are tinted various shades of light yellow and reddish brown. The material is similar in every way to the deposits lining cavities in the Bertie waterlime and to layers in

[1] C. A. Hartnagel, "Preliminary Observations on the Cobleskill ('Coralline') Limestone of New York," *N.Y. State Museum Bull. 69*, 1903, p. 1135.

[2] G. D. Harris, "The Geological Occurrence of Rock Salt in Louisiana and East Texas," *Econ. Geol.*, IV (1909), 12–34.

some of the calcareous tufa now forming in places on the surface. These fissures are possibly due to the solution and removal of underlying salt beds or perhaps to other superficial disturbances, since the deposits were evidently formed in the belt of weathering.

TYPES OF VEINS

Structurally the veins are of two different types: one fibrous, the other more or less coarsely crystalline and non-fibrous. The former are composed either of gypsum or calcite, the crystal fibers extending transverse to the strike of the veins, which run in all directions, but are generally parallel to the bedding. These veins are lenticular and continue for short distances only. The non-fibrous veins usually consist of gypsum or calcite, but the calcite veins sometimes contain accessory quartz and pyrite. They are more persistent and more uniform in width than the fibrous veins, and most of them are vertical or steeply inclined. The evidence indicates that each type had a different mode of formation.

SOURCE OF THE VEIN MINERALS

In the veins under consideration there can be no question as to the source of the vein minerals, for it is evident that they have been derived from the neighboring rocks. The veinlets found in the gypsum-bearing strata of the Salina are composed of gypsum, while those occurring in the limestones, waterlimes, and calcareous shales consist essentially of calcite. It is not the purpose of the writer, however, to imply that the vein minerals found in other and larger veins have usually had a similar source.

DESCRIPTION OF THE FIBROUS VEINS

The fibrous (satin spar) veins are larger and more abundant in the gypsum-bearing strata, probably because of the greater solubility of gypsum as compared with calcite. As a rule they are less than 3 cm. in width and from 20 to 50 cm. in length, but in places they have a width of over 10 cm. and extend for distances of many meters. Most of the veins are highly lenticular in form; where a vein thins out it may be replaced by another a little to one side, so that the ends overlap. Veins frequently split into two or

more branches, but the intersection of veins is extremely rare. When numerous they are commonly grouped to form linked-vein systems, as in Fig. 1. The vein fibers are usually normal to the inclosing walls, occasionally they are oblique, and very rarely they are curved or abruptly bent. In some veins most of the fibers apparently extend from wall to wall without a break, while in others there is a well-defined central parting frequently marked by the presence of inclusions of the wall rock. Small vugs are found in a
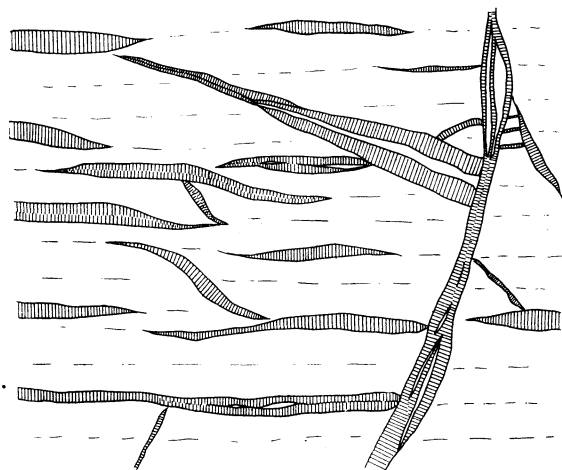

Fig. 1.—Veins of fibrous gypsum exposed in walls of quarry near Union Springs New York.

few veins, and these are lined with gypsum crystals of normal habit.

The veins of fibrous calcite are similar to those of fibrous gypsum except that ordinarily they are smaller and not so numerous. In both gypsum and calcite veins the fibrous structure is as highly developed in the larger veins as in those that are smaller, the diameter of the fibers apparently being independent of the size of the veins. However, the diameter of the crystal fibers does vary markedly with any change in the texture of the wall rock. In the fine-grained limestones and shales the fibers commonly have a diameter of 0.05 mm. and less, while in the Onondaga "gray limestone," with its coarsely crystalline texture, the diameters are as

great as 2 mm., and the fibrous structure is hardly noticeable in the narrower veins. Where veins of fibrous calcite in the Onondaga "blue limestone" pass through chert nodules, there is a sharp change in texture, the veins becoming coarsely crystalline and non-fibrous within the chert. This sudden change in texture is easily noticeable in veins that are less than a millimeter in width, when they are examined in thin sections under the microscope.

Where the veins are non-fibrous, the individual crystals usually have their longer dimensional axes parallel rather than transverse to the strike of the veins; and, especially in the smaller veins, most of the crystals extend from wall to wall. In the larger veins these crystals have maximum diameters of over 5 cm., while in the fibrous portion of the same veins the fiber crystals are uniformly 0.1 mm. or less in diameter. The larger crystals of calcite frequently show warped cleavages, and under the microscope undulatory extinction is common in these crystals and also in those of fibrous form. The fibrous crystals are very irregular in cross-section, since the prisms are not bounded by plane surfaces as is often true of the crystals found in the non-fibrous portions of the veins.

Vugs lined with calcite crystals of normal habit (simple rhombohedrons with some scalenohedrons) are occasionally present in the fibrous portion of the veins where the walls are of limestone, but they are more abundant where the veins are coarsely crystalline and have chert walls. The walls of the veins are sharply defined, and inclusions of the wall rock, limestone as well as chert, are common. When one wall of a vein contains angles or other irregularities, there are corresponding irregularities in the opposite wall, such that the two surfaces would fit closely together if placed in contact.

ORIGIN OF THE FIBROUS VEINS

In previous papers[1] the writer has cited evidence tending to prove that cross-fiber veins of the asbestiform minerals could not have been formed through any process of replacement or of recrystallization *in situ* and that they were not deposited in open fissures.

[1] Stephen Taber, "The Origin of Veins of the Asbestiform Minerals," *Proc. Nat. Acad. Sci.*, II (1916), 659–64; and "The Genesis of Asbestos and Asbestiform Minerals," *Bull. Am. Inst. Min. Eng. No. 119*, 1916, pp. 1973–98.

Most of the objections raised against these theories of vein formation are equally applicable in the case of the veins of fibrous calcite and gypsum; and, in the descriptions given above, much confirmatory evidence may be found. All of the structural features characteristic of these veins have been duplicated in fibrous veins grown in the laboratory where their origin and growth could be observed in detail.[1] In view of all the facts obtained from field investigations and laboratory experiments, the conclusion is inevitable that the veins of fibrous calcite and gypsum have been formed through a process of lateral secretion, the growing veins making room for themselves by pushing apart the inclosing walls, and that the fibrous structure is due to the circumstance that the material for crystal growth was accessible in only one direction.

Calcite and gypsum are not normally fibrous, and wherever they have developed this structure it is due to the physical conditions which have prevented crystal growth, except in one direction. Merrill has described fibrous incrustations of gypsum forming on the walls of caves, and notes that the growing crystals not infrequently force off pieces of the limestone of considerable size.[2]

Laboratory experiments and field investigations indicate that the essential conditions for the growth of fibrous minerals, such as calcite and gypsum, are: (1) the growing crystals must be in contact at their base with a supersaturated solution; and (2) the solution must be supplied through closely spaced capillary or subcapillary openings in the surface of the wall rock. In the fine-grained limestones and shales the constituent particles are relatively small, and therefore the open spaces which are chiefly subcapillary in size are closely spaced; but in the crystalline "gray limestone" with its coarser texture these openings while no larger are necessarily more widely spaced. This explains the coarse texture of the fibrous veins occurring in the "gray limestone." The coarsely crystalline non-fibrous structure of veins where they pass through chert masses is due to the relative impermeability of the chert which has here

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[1] Taber, "The Origin of Veins of the Asbestiform Minerals," *Proc. Nat. Acad. Sci.*, II (1916), 659–64; and "The Genesis of Asbestos and Asbestiform Minerals," *Bull. Am. Inst. Min. Eng. No. 119*, 1916, pp. 1973–98.

[2] G. P. Merrill, "On the Formation of Stalactites and Gypsum Incrustations in Caves," *Proc. U.S. Nat. Mus.*, XVII (1894), 81.

prevented the addition of new material directly through the walls, thus forcing it to reach the growing crystals by diffusing between the walls. Vugs result from a deficiency of material necessary for growth because of insufficient concentration or because of relative inaccessibility. The latter probably explains the greater abundance of vugs between chert walls.

DESCRIPTION OF THE NON-FIBROUS VEINS

The non-fibrous veins range up to 5 cm. or more in width and in some instances are exposed for distances of 15 or 20 m. along the strike. Where they pinch out and disappear, they are sometimes replaced by others a few centimeters to one side or farther along the line of strike. Such vein systems may be traced for over 50 m. The veins show no appreciable change in appearance where they pass from one rock to another of different texture or composition. A vein exposed in the limestone quarry near Farleys can be traced upward through the argillaceous Manlius limestone, 20 cm. of Oriskany conglomerate, and into the Onondaga limestone, yet at no place is any variation in its appearance perceptible.

The vein walls are sharply defined, and fracture usually takes place more readily along the contact between vein and wall rock than in other directions. The opposite walls of a vein are parallel even when they are very irregular, and they would therefore fit intimately together if placed in contact (see Fig. 2). Angular fragments of the wall rock are occasionally present in the veins; and in many instances, by making parallel sections, it is possible to prove that they are in contact neither with other fragments nor with the walls. Most of the fragments show no evidence of rotation although they have been displaced through distances of 2 cm. or more (see Fig. 3). In places a fragment adhering to both walls of a vein appears to have been separated into several fragments by continued vein growth, as in Fig. 4.

Some veins have a banded structure with coarsely crystalline non-fibrous calcite in the center and a band of fibrous calcite along each wall. This is probably due to two stages of vein growth, as is indicated by the veins sketched in Fig. 2. Other veins are roughly banded, with pyrite along the walls and calcite in the center (see

Fig. 5), but in such cases the pyrite was deposited subsequent to the deposition of most of the calcite, and well-formed cubes and pyritohedrons may be found replacing impartially vein calcite and wall rock. Small seams of pyrite in places cut directly across the veins.
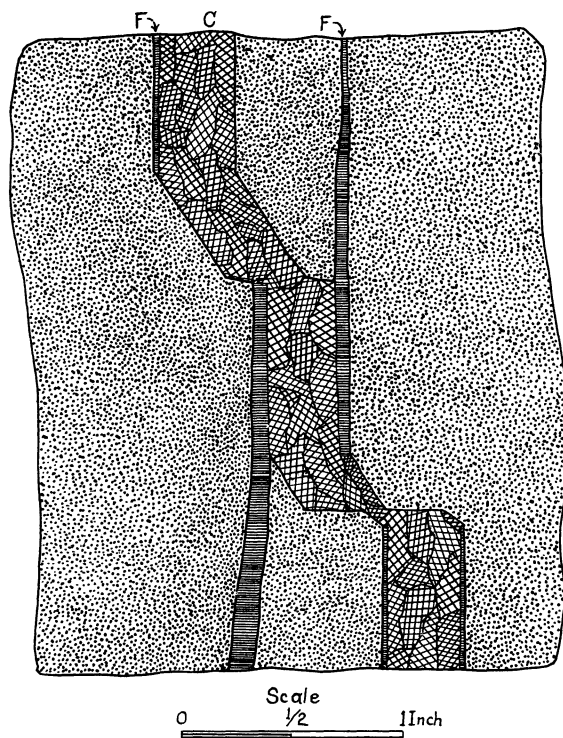

FIG. 2.—Calcite veins in limestone. Coarsely crystalline calcite (*C*) and fibrous calcite (*F*).

ORIGIN OF THE NON-FIBROUS VEINS

The facts cited above preclude the theory that these veins are due to recrystallization of country rock *in situ* or that they could have been formed through replacement; and the presence of detached inclusions of wall rock argues against the hypothesis that the veins were deposited in open fissures. If the veins were formed as a result of fissure filling, deposition of vein matter must have begun on the walls and continued inward until the opposite sides

met, thus forming a suture line near the center, but there is no evidence that such a suture was ever present in any of the veins under consideration. Large calcite crystals commonly extend without interruption from wall to wall, and in one vein a well-formed crystal of quartz, with a pyramid at each end of the prism,
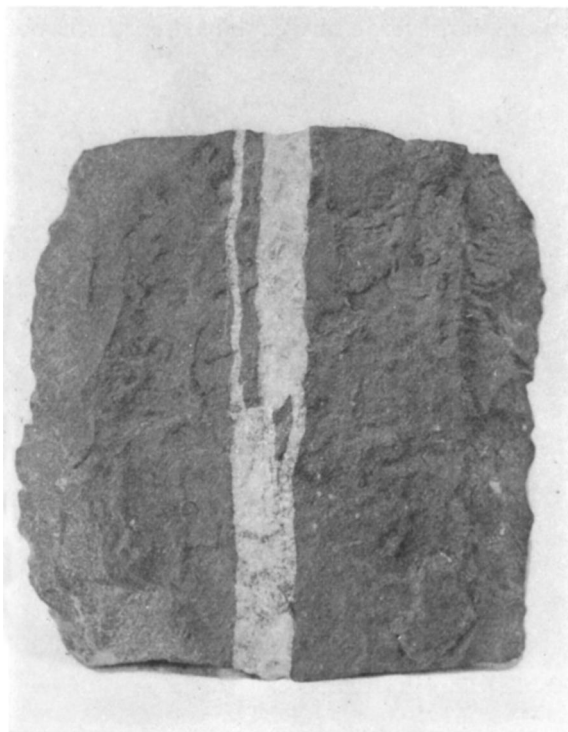

FIG. 3.—Calcite vein in limestone showing angular inclusion of the wall rock. Two-thirds natural size.

was found extending across almost the entire width of the vein (see Fig. 5).

The best evidence bearing on the origin of the veins is, perhaps, furnished by certain chert nodules containing veinlets of calcite, ranging up to 2 or 3 mm. in width, which do not extend into the inclosing limestone (see Fig. 6). The force separating the chert walls was applied so gradually that any stresses set up in the

limestone were adjusted by recrystallization, in the same way that slabs of marble or limestone may be slowly deformed under forces acting through a long period of time. This process probably also explains the curving walls of the lenticular veins.

The facts here listed are difficult or impossible of explanation under any of the hitherto generally accepted theories of vein formation. They are, however, easily explained on the hypothesis that

Fig. 4.—Calcite veins in limestone showing inclusions of the wall rock. Two-thirds natural size.

the vein-forming solutions entered along fractures, bedding planes, or other planes of weakness, where the openings were chiefly capillary or subcapillary in size; and that the separation of the vein minerals from solution was accompanied by the development of a force sufficient in magnitude to push apart the walls, and thus gradually make room for the growing veins. Circulation of solution through such narrow openings must necessarily be extremely slow, and under these conditions diffusion through the solution becomes an important factor in supplying additional material to the growing crystals.

Where veins pass through chert masses, most of the calcite crystals extend from wall to wall, and are oriented with their longer dimensional axes parallel rather than transverse to the vein walls— a fact that is likewise true of many non-fibrous veins in limestone and shale. Since this may be observed in the largest as well as the smallest veins, it means that the average number of vein crystals
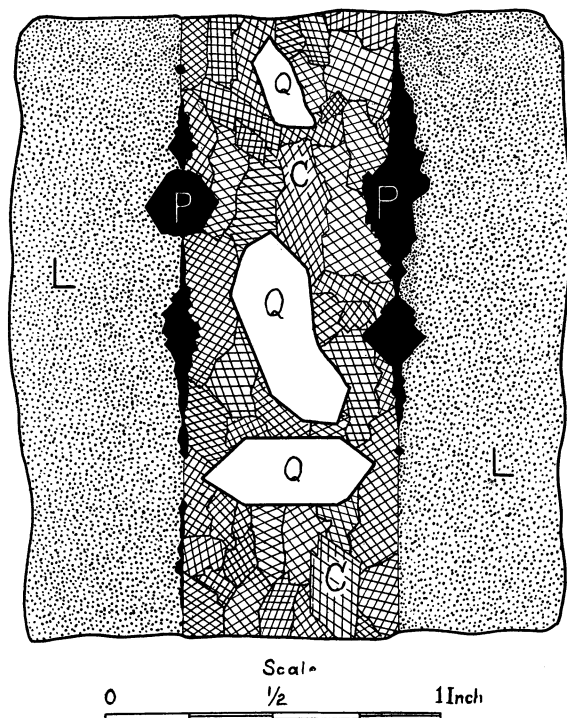

Scale
0 _____ ½ _____ 1 Inch

FIG. 5.—Vein consisting of calcite (*C*), pyrite (*P*), and quartz (*Q*), with walls of limestone (*L*). The pyrite replaces both the limestone and the vein calcite.

in contact with unit area of the wall tends to decrease with the growth of the vein. In other words, it is believed that with continued growth those crystals having any advantage, because of greater size, or more favorable orientation or location, tend to increase in size partly at the expense of their less fortunate neighbors. This conclusion is supported by the manner in which the inclusions have been displaced in some of the veins. The

enlargement of certain crystals at the expense of others does not, however, continue indefinitely.

NATURE OF FORCES THAT SEPARATED THE VEIN WALLS

It has been demonstrated that under suitable conditions crystal growth is accompanied by the development of a force which may even exceed the crushing strength of the crystals. The nature of
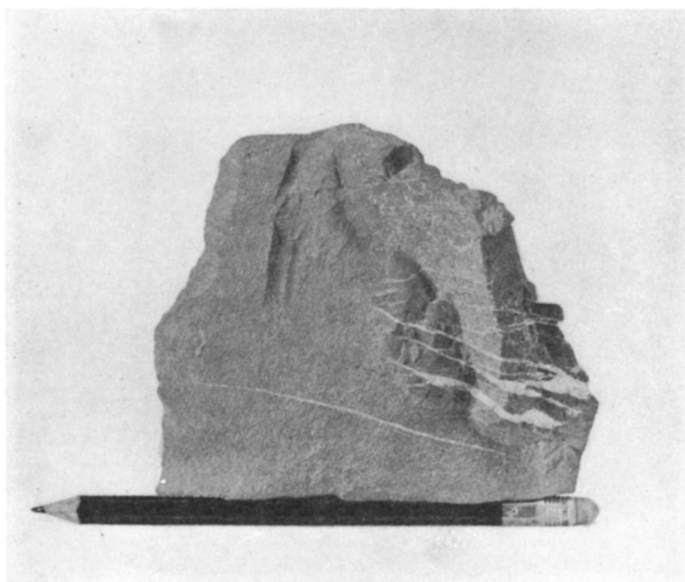

FIG. 6.—Chert nodule containing calcite veinlets which do not pass into the inclosing limestone. Two-thirds natural size.

this force has been discussed in several recent papers. Bruhns and Mecklenburg ascribe the pressure effects accompanying crystal growth to the "forces of adsorption and capillarity."[1] This has been refuted by Becker and Day and independently by the present writer. Becker and Day published a paper "with the purpose of demonstrating . . . . the existence of a linear force, apart from the volume expansion, exerted by growing crystals." They conclude (1) that

[1] W. Bruhns and Werner Mecklenburg, "Über die sogenannte 'Kristallisationskraft,'" *Jahresbericht der Niedersächsischen geologischen Vereins zu Hanover*, VI (1913), 106–8.

this force enables a crystal to grow in directions in which growth is opposed by external force "notwithstanding unrestricted opportunity for growth in other directions; (2) that the linear force thus exerted is of the order of magnitude of the breaking strength of the crystal."[1] Most of the phenomena that have been cited in support of the latter hypothesis may be explained, however, by the fact that the growing crystals have been in contact with a supersaturated solution in only one direction, or that the concentration of the solution has been greater in one direction than in others. The present writer believes that the pressure effects accompanying crystal growth are to be attributed chiefly to the molecular forces associated with the separation of solids from solution, and that the tendency to develop crystal faces is of minor importance.[2] Argument in support of this hypothesis has been given elsewhere.[3]

According to the writer's concept, the pressure developed during crystal growth is due, in most cases, to the fact that the solid can diffuse through a solution occupying small capillary or subcapillary spaces, while the crystalline mass built up by the separation of the solid from solution cannot escape through the small openings in like manner, even when under great pressure. The force observed during the separation of crystals from solution is believed to be analogous to the pressure developed when an anhydrous salt, confined in a limited space, combines with water that has diffused as vapor through capillary openings.[4] The diffusion of the solid through the solution is ascribed to osmotic pressure, and its separation therefrom to the relation between osmotic pressure and solution pressure.

Crystals grow through the addition of layers of material to their outer surfaces, and this can take place only when the surfaces are in contact with a layer of supersaturated solution, the concentration

[1] G. F. Becker and A. L. Day, "Note on the Linear Force of Growing Crystals," *Jour. Geol.*, XXIV (1916), 313.

[2] Stephen Taber, "The Growth of Crystals under External Pressure," *Am. Jour. Sci.*, Series 4, XLI (1916), 553–54.

[3] Stephen Taber, "Pressure Phenomena Accompanying the Growth of Crystals," *Proc. Nat. Acad. Sci.*, III (1917), 297–302.

[4] Stephen Taber, "The Genesis of Asbestos and Asbestiform Minerals," *Bull. Am. Inst. Min. Eng. No. 119*, 1916, pp. 1986–87.

of which is maintained by diffusion from without. When a crystal grows in a direction in which growth is opposed by external pressure, the pressure is transmitted through a thin layer of solution separating the crystal from the foreign body. The effect of pressure and of capillarity, if the latter be present, is to reduce the thickness of this layer to a minimum; but it would be difficult, if not impossible, to completely expel it by pressure alone from between two smooth parallel surfaces. And crystal growth would tend to make the surfaces under pressure parallel, for deposition would be most rapid where diffusion is least restricted, i.e., where the layer of solution is thickest. Therefore a crystal growing in a limited space may make room for itself by forcibly enlarging this space, if it is supplied with the material for growth by diffusion through solutions occupying spaces that are sufficiently small.

The solubility of most substances, including calcite, is increased by pressure, and when such a substance separates from solution, there is an increase in volume which may result in pressures greatly exceeding the crushing strength of the crystals, provided the solution cannot readily escape. If the material that incloses a growing crystal is rendered more soluble by pressure, it may be gradually removed in solution as the crystals are enlarged. This probably explains the replacement of limestone and vein calcite by the idiomorphic crystals of pyrite.

The tendency of a crystal to assume a regular polyhedral form is important as a factor in the development of pressure during crystal growth only in so far as it affects the relative solubility of the crystal in different directions. While the difference in the pressure that may be developed in any two directions during the growth of a crystal is probably small, it can accomplish appreciable results if continued through a long enough period of time.

SUMMARY AND CONCLUSIONS

The small and relatively simple veins of a region of unaltered sedimentary rock were studied in order to obtain field evidence bearing on the mechanics of vein formation. Two types of veins are described, one fibrous and the other coarsely crystalline and non-fibrous. Both consist essentially of calcite or of gypsum.

According to the author's theory, the fibrous veins owe their peculiar structure to the fact that the material for growth was supplied only to the base of the growing crystals through solutions occupying closely spaced capillary or subcapillary openings in the walls, while the non-fibrous veins were deposited from solutions that entered between the walls of narrow capillary fractures and bedding planes. Because of the slow rate of circulation through such minute spaces, diffusion through the solution is probably an important factor in supplying material to the growing veins.

The diameter of the calcite and gypsum fibers varies with the spacing of the openings through which the material for their growth is supplied, and is independent of the size of the veins. There is evidence of some recrystallization within the non-fibrous veins during the process of growth, as a result of which those crystals that for any reason are less stable than their neighbors are redissolved, thus furnishing additional material for the growth of others.

The field evidence, confirmed by laboratory experiments, indicates that the veins were not deposited in pre-existing openings, but that the growing veins have made room for themselves by pushing apart the inclosing walls. The presence of drusy cavities, banding, or crustification are not in themselves proof that a vein was deposited in a pre-existing open fissure.

The force that enables a growing vein to make room for itself is attributed chiefly to the molecular forces associated with the separation of solids from solution.